

The Occurrence of Earth-Like Planets Around Other Stars

Will M. Farr^{1,2}, Chris Aldridge^{1,3}, Kirsty Stroud^{1,4} & Ilya Mandel^{1,5}

¹*School of Physics and Astronomy, Univeristy of Birmingham, Birmingham, B15 2TT, United Kingdom*

²*w.farr@bham.ac.uk*

³*CXA064@bham.ac.uk*

⁴*KLS081@bham.ac.uk*

⁵*ilyamandel@chgk.info*

The quantity η_{\oplus} , the number density of planets per star per logarithmic planetary radius per logarithmic orbital period, describes the occurrence of Earth-like extrasolar planets. Measurement of η_{\oplus} is complicated by the difficulty of detecting Earth-like planets in Earth-like orbits about Sun-like stars; previous estimates place $1\% \lesssim \eta_{\oplus} \lesssim 34\%$, relying on extrapolations from regions in period-radius space where detection is easier and the sample of observed planets is complete^{1–3}, or modelling the selection effects carefully but using simpler models of the period-radius distribution of exoplanets⁴, possibly using a low-noise subset of the available data⁵. Additionally, no previous estimates account for contamination from false-positive planetary identifications. Here we present constraints on η_{\oplus} from a parameterised forward model of the (correlated) period-radius distribution and the observational selection function in the most recent (Q17) data release from the Kepler satellite^{6–8}, including an empirical parameterisation for the distribution of false-positives in the data set. We find $\eta_{\oplus} = 4.1^{+2.3}_{-1.7}\%$

(90% CL). Additionally, we find that each star hosts $4.04^{+0.85}_{-0.68}$ planets with $P \lesssim 3\text{yr}$ and $R \gtrsim 0.2R_{\oplus}$, that the peak of the planet-radius distribution lies at $R_{\text{peak}} = 1.19^{+0.17}_{-0.18}R_{\oplus}$. Will: [More science stuff here.](#)

1. Wittenmyer, R. A. *et al.* The Frequency of Low-mass Exoplanets. III. Toward η_{\oplus} at Short Periods. *The Astrophysical Journal* **738**, 81 (2011). [arXiv:1103.4186](#).
2. Catanzarite, J. & Shao, M. The Occurrence Rate of Earth Analog Planets Orbiting Sun-like Stars. *The Astrophysical Journal* **738**, 151 (2011). [arXiv:1103.1443](#).
3. Traub, W. A. Terrestrial, Habitable-zone Exoplanet Frequency from Kepler. *The Astrophysical Journal* **745**, 20 (2012). [arXiv:1109.4682](#).
4. Dong, S. & Zhu, Z. Fast Rise of "Neptune-size" Planets ($4\text{--}8 R_{\oplus}$) from $P \sim 10$ to ~ 250 Days—Statistics of Kepler Planet Candidates up to ~ 0.75 AU. *The Astrophysical Journal* **778**, 53 (2013). [arXiv:1212.4853](#).
5. Petigura, E. A., Howard, A. W. & Marcy, G. W. Prevalence of Earth-size planets orbiting Sun-like stars. *Proceedings of the National Academy of Science* **110**, 19273–19278 (2013). [arXiv:1311.6806](#).
6. Borucki, W. J. *et al.* Kepler Planet-Detection Mission: Introduction and First Results. *Science* **327**, 977– (2010).

7. Borucki, W. J. *et al.* Characteristics of Planetary Candidates Observed by Kepler. II. Analysis of the First Four Months of Data. *The Astrophysical Journal* **736**, 19 (2011). [arXiv:1102.0541](#).
8. Batalha, N. M. *et al.* Planetary Candidates Observed by Kepler. III. Analysis of the First 16 Months of Data. *The Astrophysical Journal Supplement* **204**, 24 (2013). [arXiv:1202.5852](#).

Acknowledgements WMF and IM are supported by a STFC consolidated grant number NNNN. Computations in this work were performed on the University of Birmingham’s BlueBEAR cluster. Some/all of the data presented in this paper were obtained from the Mikulski Archive for Space Telescopes (MAST). STScI is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. Support for MAST for non-HST data is provided by the NASA Office of Space Science via grant NNX13AC07G and by other grants and contracts. This paper includes data collected by the Kepler mission. Funding for the Kepler mission is provided by the NASA Science Mission directorate.

Author Contributions All authors assisted in the computational modelling, discussed the results, and edited the manuscript.

Reprints Reprints and permissions information is available at www.nature.com/reprints.

Competing Interests The authors declare that they have no competing financial interests.

Correspondence Correspondence and requests for materials should be addressed to W.M.F. (email: w.farr@bham.ac.uk).